8 YEARS EXPERIENCE IN AVALANCHE DETECTION BY USING A PULSE DOPPLER RADAR

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ABSTRACT: Nowadays, artificial release of avalanches for road and slope safety is very common. To do so safely, a reliable detection and monitoring system in any weather and light condition (rain; snowfall, fog, wind, night etc.) is required. Parameters for detecting and characterizing avalanches are volume, mass and the velocity distribution. A known technology to measure velocities very accurate is the RADAR-Technology using the Doppler-Effect on moving objects. The RADAR cross-section of an object for a given wavelength is a function of the magnitude, material, incident and reflecting angle, which determines the scattered intensity. Therefore, this reflected intensity is a parameter that belongs to the cross section of the moving volume of the detected object. So, RADAR-technology is able to measure both magnitude and the velocity distribution. It is also needed, that a monitoring and alarming system should detect all events without missing one and it should of course detect only events and minimize false alarms. According to the “Projekt Lawinendetektion Schlussbericht” (Lussi et al., SLF, 2012) of all known technologies only the Radar can fit all this needs. Till now there have been Radars of this type running for years in Ischgl, Kappl, Feichten, St. Leonhard, Sölden and hundreds of spontaneous and triggered avalanches are detected so far. After the first season of each installation of a Radar the trigger levels can be adjusted so, that the detection quote is nearly 100% (even for the smallest avalanches) and the false alarm quote goes to 0 %.

KEYWORDS: Avalanche Radar, Avalanche Detection, Alarming System, Monitoring System

1. INTRODUCTION

The artificial avalanche release becomes more and more important for slopes, roads and other kind of infrastructure protection. The success of the blasts can hardly be visually checked in poor visibility or during nighttime. According do the “Projekt Lawinendetektion Schlussbericht” (Lussi et al., SLF, 2012) of all known detection technologies only a Radar can be reliable for this task. Furthermore, as there is also the spontaneous avalanche activity detected, it provides valuable information on the local avalanche situation in respect of frequency and magnitude. A vision-independent avalanche detection system gives therefore important information for decision-makers in the security services especially for security services of traffic routes. The here presented Pulse Dopper Radar device was already successfully tested for snow avalanches in Sedrun/Switzerland (Lussi et al., 2012) and in Ischgl/Austria (Kogelnig et al., 2012).

2. RADAR TYPES BASIC

As there are different RADAR operation modes in use and not everyone is familiar with them, a short and rough overview helps to choose the best one for avalanche detection.

2.1 <u>CW-Radar</u>

A **C**ontinuous **W**ave Radar emits continuously a sinusoidal HF signal with constant amplitude. The on a target reflected wave comes back to the receiver and the phase shift is measured. Therefore, this Radar type is well suited for length-change measurements in the 1/2 wavelength regime.

2.2 <u>CW-Doppler Radar</u>

A modification to the simple CW-Radar is the CW-Doppler Radar. Here the frequency shift of the reflected wave by moving objects, the so called Doppler Shift, is measured. The magnitude of the shift and the sign correspond directly to the velocity of the moving object. This kind of Radar is for example used as a motion detector.

2.3 <u>FMCW Radar</u>

If you want measure both the velocity and the distance of an object, you have to shift the frequency of the continuous wave periodically and you will get a FMCW (frequency modulated continuous wave) Radar. This kind of Radar is used for distance measurements, for speed control and so on, it is limited for multiple targets measurement in different distances and with different velocities.

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2.4 Pulse Doppler Radar

If you want to measure multiple targets with different velocities in the same or in different distances you have to use more complex type of Radar a Pulse Doppler Radar. The Radar emits a pulse and measure on the one hand the time to the received echo and on the other hand the Doppler-Shift to obtain the velocities. With this type you can measure different objects with different velocities all at once.

3. PRINCIPLE OF THE USED PULSE COMPRESSION DOPPLER RADAR

The RADAR operates according to the principle of the coherent pulse Doppler RADAR. A high-frequency generator produces a signal in the X-band (10.425 GHz). This signal is pulse-modulated in a high-frequency switch, amplified to an output power of about 1 W and radiated from a parabolic Antenna to the detection area. The reflected beam from the observed area passes the parabolic Antenna again and goes through the receiver. In the receiver the reflected signal is sampled and goes to the analog-digital converters. Afterwards, a digital signal processor calculates the measured values from the signal, which then are edited and displayed on a user interface or go through an automatic alarm generating software.

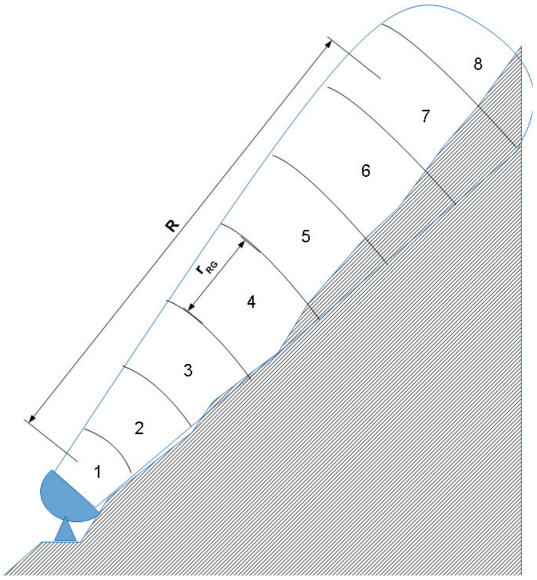

Figure 1: Scheme of typical detection situation with different range gates numbers n, range gate length r_{RG} and a range R.

Figure 1 shows the illumination of a mountain slope with a pulse-shaped electromagnetic wave packet limited to discrete points in time. The discrete time points 1-8 are located exactly at the distance of spatial pulse length corresponding to range gate length r_{RG}. It is assumed that an electromagnetic wave is emitted with duration τ. The speed of the pulse in the propagation medium air is the speed of electromagnetic wave c in the medium air. Thus, one range gate length is

$$r_{RG} = \tau . c \qquad (1)$$

and the discrete time points become $n.\tau$ or in space $n.r_{RG}$. This means, after the time t, the wave packet is at distance R from the antenna. From Figure 1 we get the conclusions that the beam direction of the antenna should be oriented almost parallel to the slope in order to illuminate the maximum range of the slope and get as many range gates as possible.

The space-resolution is equal to the range gate length r_{RG} and is therefore also a linear function of the duration time τ. The duration time itself influences the signal to noise ratio of your data in the way the longer the duration time is the better the signal to noise ratio will be.

The pulse repetition frequency of the RADAR device is up to 90 kHz, this means that every second data from 90000 pulses is processed, which gives typically about 3 frames per second for the analysis (one frame example you can see in Figure 2). The maximum range for detecting moving objects (even snow) with a cross section of 1m² in heavy weather condition (rain/snow) is 2 km. The range gate length is chosen between 15 m and 250 m and it is possible to measure velocities between 1 km/h and 300 km/h.

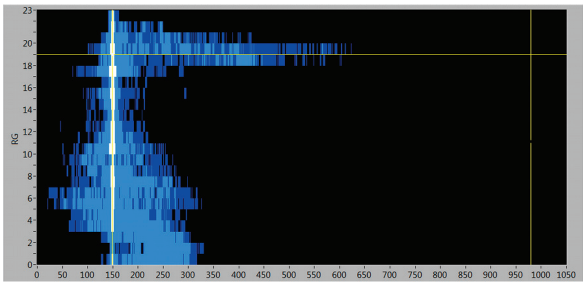

Figure 2: Typical Frame of Radar raw Data showing a small avalanche between RG 18-21 (2000-2150 m distance) in very heavy rain condition (RG 0-12). Y-Axis: RG-number 0-23 (ca. 1250m to 2200m from the Radar). X-Axis: velocities between 0 and 20 m/s; 0 m/s Line at channel 150.

Figure 2 shows impressive the performance of a Pulse Compression Doppler Radar. Although there is a heavy rainfall between radar and avalanche, you can clearly see the avalanche. This is possible because in each RG the velocity distribution is obtained separately.

We have developed an algorithm that detects avalanches of other targets (rain, animals, skiers, helicopters etc.) in the radar data within a few frames (typically 5) and thus can issue an alarm (with SMS , email, etc.) or can trigger any alarming system within the first 1-2 seconds.

In parallel, a customer can, for example, follow a schematic representation of the avalanche on a screen in real time. The image shows him the affected area as well as the size of the avalanche in case of an artificial release.

4. EXPERIENCES OF THE LAST 8 YEARS

4.1 Radar Locations for Road Safety

After the first prototype was installed in Sedrun, Switzerland 2010, which was part of the comparison project of the SLF we installed the first commercial Radar together with Wyssen Avalanche Control Towers for road safety Paznaun Valley Road in Ischgl (Figure 3), Austria in the year 2011.

2012 followed again together with Wyssen Avalanche Control installations in Kappl (Figure 4), Austria, for road safety Paznaun Valley Road, and in Feichten (Figure 5), Austria for the Kaunertal Road safety.

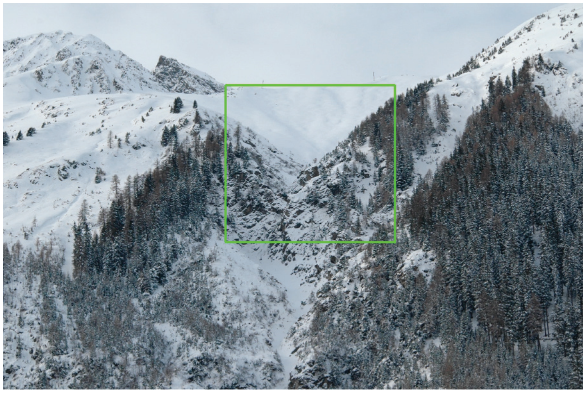

Figure 3: Location Ischgl. Green rectangle shows the monitored area (distance to the Radar: 800m-1960m).

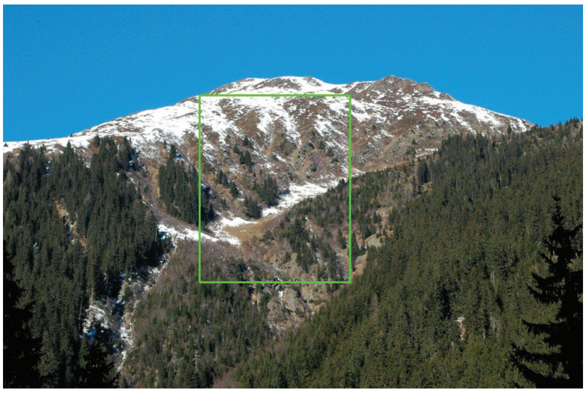

Figure 4: Location Kappl. Green rectangle shows the monitored area. (distance to the Radar: 900m-2100m).

2015 the first Radar with two Antenna-technology for two slopes was installed in St. Leonhard, Pitztal (Figure 6), Austria together with blasting systems from the MND/TAS Group.

2017 a two Antenna Radar System, this time with Inauen-Schätti AG blasting systems, was installed in the Vent-Valley (Figure 7), Sölden, Austria.

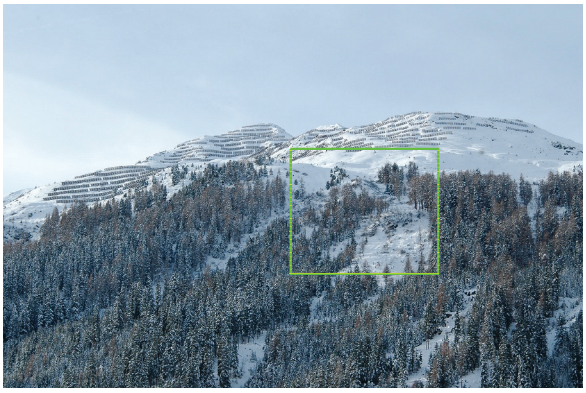

Figure 5: Location Feichten. Green rectangle shows the monitored area. (distance to the Radar: 1500m-2200m).

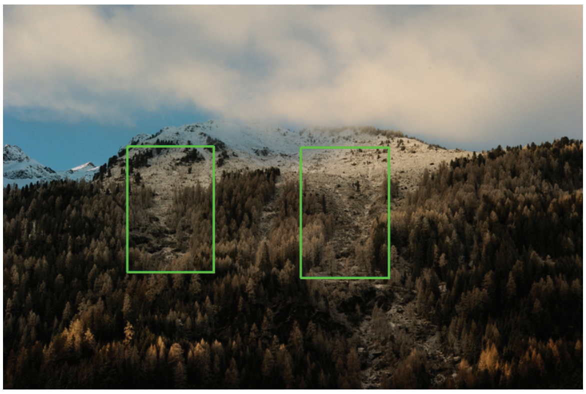

Figure 6: Location St Leonhard. Green rectangles show the monitored areas. (distance to the Radar: both: 800m-2000m).

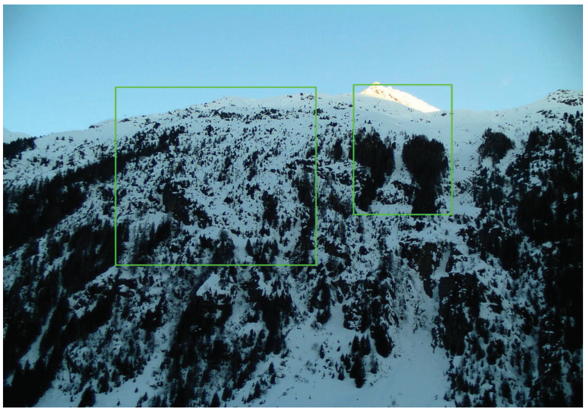

Figure 7: Location Sölden. Green rectangles show the monitored areas. (Distance to the

Radar right: 200m-2200m. Distance to the Radar left: 200m-1200m).

4.2 Results and Experiences

In general one can notice that after installing a radar with the basic setting for the live observation in case of artificial release the radar is fully operational. For the optimal parameterization it needs 1-3 avalanches. For the alarming function we always have done the conservative way, this means we have tuned the parameters from very sensitive (to obtain every moving objects, also with the possibility to have some false positive alarm) to accurate sensitive just for not missing any avalanches.

We learned that every location is a little different. In Ischgl and Kappl there is a higher possibility for rainy conditions and spontaneous avalanches happens very frequently, although the artificial triggering of the avalanches is used very often. In Feichten there are just 1 to 3 avalanches a year. In St. Leonard Pitztal after two winters with just a few avalanches we had 17/18 a winter with several avalanches. In Vent Valley, Sölden there were a lot of avalanches detected and additional at this location there is a lot of movement of different other objects (helicopter, eagle, skiers, animals), so the tuning of the parameters takes several events. In general, after 1 year experience with different events on a new location the false alarm rate goes to 0. An overview of all location is listed in Table 1.

Table 1: Results for the different Locations

Radar Location	**Year of inst.**	**Alarm and Avalanche**	**Alarm but no Avalanche**	**No Alarm but Avalanche**
Ischgl	**2011**	**72**	**3***	**0**
Kappl	**2012**	**287**	**7***	**2*****
Feichten	**2012**	**8**	**1****	**0**
St. Leonhard	**2015**	**24**	**0**	**0**
Vent-Valley	**2017**	**30**	**4*******	**0**

* all alarms on one evening within 2 hours caused by a heavy rain shower in January; new algorithms can handle this.
** Module defect
*** Radar detected the avalanche, but the phone connection was broken
**** Rain, eagle, skiers; with the data of the first year we will be able to handle this

4.3 Radar Availability

For monitoring and alarming systems the availability time is very important. All Radar stations are online monitored in respect of function and performance. At the starting of the season an onsite inspection is done, and the antenna alignment is checked. The active time should be from November to May for 24 hours each day. If a component is broken, it should be replaced as soon as possible.

For all 5 station we had till now 1 broken Radar Module (just a fuse inside), 1 PC and 1 Rooter. The Radar Module in Ischgl showed some miss function once or twice a week in the last season and has to be restarted than (automatically within our monitoring program). Overall the dead time in sum was only 6 days for all stations over all year

5. CONCLUSION

After 8 years of experience with the Pulse Doppler Avalanche Radar in combination with the artificial avalanche release all expectations have been fulfilled. The Avalanche Radar is a very useful and reliable tool for the responsible on site. With the instrument it is possible to release the avalanche at any weather condition and in any visibility. Spontaneous avalanches are detected very accurate and the false alarm rate becomes neglectable, if the instrument is set well.

All radar systems showed a very good weatherability in the long-term use and under hardest weather conditions.

REFERENCES

Kogelnig, A., Wyssen, S., Pichler, J. (2012): Artificial release and detection of avalanches: Managing avalanche risk on trafic infrastructures, a case study from Austria, Congress contribution ISSW 2012.

Lussi, D., Schoch, M., Meier, L., Rüsch M. (2012): Projekt Lawinendetektion Schlussbericht, WSL-Institut für Schnee- und Lawinenforschung SLF